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Comparison of Cost for the NbTi and Nb3Sn 10 Tesla Magnets

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The maximum cost effective field limit for the NbTi superconducting accelerator magnets is 7 T at 4.3 K and 10 T at 1.9 K. D19 dipole magnet (the high field modification of SSC 50 mm dipole) had reached 10.1 T at 1.9 K with the SSC superconductor having the critical current density of 2.75 kA/mm^2 at 5 T and 4.2 K or 1.65 kA/mm^2 at 10 T and 1.9 K. A further increase of maximum field could be achieved using Nb3Sn (or some others A15 superconductors) or HTS. Nb3Sn short dipole models with magnetic field 11-13 T have been developed and tested by UT and LBNL groups.

Now it is established that Nb3Sn is a most cost-effective superconducting material for the application in accelerator magnets with magnetic field up to 15 T. This material is brittle and thus produces additional difficulties with it application in accelerator magnets. However, a significant progress in superconductor and high field magnet technology has been achieved during past years. The Nb3Sn high current density conductors, commercially available now, provide the comparable critical current density of 1.4-1.6 kA/mm^2 at 12 T and 4.2 K. This allows one to compare the relative cost of 10 T dipole magnets made of NbTi and Nb3Sn conductors and having the same cross-section.

The cost estimate has been done based on the RHIC magnet cost structure /1/. This structure for the one layer RHIC dipole is summarized in Table 1.

Table 1. One layer (RHIC) magnet cost structure.

	M&S	Labor	Total
Coils	18%	11%	29%
Cold mass	21%	13%	34%
Cryostat	23%	14%	37%
Total	62%	38%	100%

As it can be seen from the table, M&S is 62% and Labor is 38% of the total RHIC cost. The coil, cold mass and cryostat M&S and Labor provide approximately equal contribution to the total RHIC magnet cost.

The magnetic field of 10 T can be achieved with at least a two-layer coil design. The cost structure of the 10 T NbTi magnet, obtained by scaling RHIC cost structure to the two layer design with the SS collars required for the high field magnet, is summarized in Table 2. These results do not include the change of cryostat cost for the NbTi 10 T magnet operating at 1.9 K.

Table 2. Cost structure of two-layer 10 T magnet made of NbTi superconductor.

	M&S	Labor	Total
Coils	25%	15%	40%
Cold mass	22%	11%	33%
Cryostat	16%	11%	27%
Total	63%	37%	100%

As it follows from the table, the relative contribution of M&S and Labor to total magnet cost is still practically the same, 63% and 37%.

To estimate the cost of 10 T Nb3Sn magnet the price of superconductor has been increased by factor of 2-5. Factor of 5 represents a present price ratio, factor of 2 is expected for the large scale production. Coil fabrication labor has been increased by factor of 2. This number reflects current relationship in coil fabrication labor. It should be studied more attentively, its possible reduction at magnet mass production should be also expected. The estimated cost structure for the 10 T Nb3Sn magnet is summarized in Table 3.

Table 3. Estimated cost structure of two-layer 10 T magnet made of Nb3Sn superconductor.

	M&S	Labor	Total
Coils	50-125%	30%	80-155%
Cold mass	22%	11%	33%
Cryostat	16%	11%	27%
Total	88-163%	52%	140-215%

As it follows from Table 3, relative cost of Nb3Sn and NbTi 10 T magnets is within 1.4-2.2. Assuming a more complicate and expensive cryostat, required for the operation of NbTi 10 T magnet at 1.9 K, the real difference in magnet cost is even smaller. The Nb3Sn magnet cost increase is determined, first of all, by the higher price of Nb3Sn superconductor and then by the slightly higher coil fabrication cost. These two factor must be in a focus of high field accelerator magnet R&D program.

To make the magnet design for the field above 11 T cost effective a significant improvement of the critical current density in Nb3Sn conductor is required. The coil fabrication technology and the coil support structure have to be also optimized. However, there are some indications that the magnet cost normalized by field integral for the Nb3Sn magnet could be the same up to higher field (>11-12 T).

REFERENCES

1. E. Willen, “ Superconducting Magnet Costs”, Presentation at 33d Erice Workshop on “Superconducting Accelerator and Detector Magnets”, Erice, Italy, August 3-7, 1997.